The 27-Day Period (Interval) in Terrestrial Magnetism.

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(Received April 10, 1922.)

§ 1. The so-called 27-day period has been considered by me in several previous papers.* In these there were at my disposal homogeneous results from only a short period of years, while data were wanted from a long period to enable an adequate comparison to be made of magnetic and solar phenomena.

With the aid of a grant from the Government Grant Committee, the daily ranges in the Kew declination curves have now been measured back to 1858, when registration commenced. Use is now made of all the data up to 1900. Owing to the magnetograph being out of action, 1874 had to be omitted, leaving a total of 42 years. Subsequent to 1900 train and tram disturbances introduced some uncertainty. For the present purpose this would not have been serious prior to 1916. Declination ranges had, however, not been measured between 1900 and 1910, and the labour available seemed better devoted to other purposes, in view of the existence of the international "character" figures published at De Bilt from 1906 onwards. For the present investigation these supply ideal material. I have used some of this material before, but data from a number of additional years have since become available, and it seemed desirable to contrast the international data from the 15 years 1906–1920 with the 42 years' Kew declination data.

I propose to consider (1) how the phenomena vary from year to year, (2) how they vary with the season of the year. In either case the international data are considered first, as their representative character cannot be questioned. They are based on independent estimates of disturbance, made at a number of stations in different parts of the world. Comparatively few of the stations, it is true, are in the southern hemisphere, but it has been found that, even in the Antarctic, days of much and little disturbance accord wonderfully well with the international figures.†

The international scheme consists in each station allotting to each day a "character" figure (0 = quiet, 1 = moderately disturbed, 2 = highly disturbed). The international "character" is the mean of the figures allotted. It is given to the nearest 0·1, so that 0·0 and 2·0 represent the extremes.

* 'Phil. Trans.,' A, vol. 212, p. 75, and vol. 213, p. 245; 'Proc. Physical Society of London,' vol. 27, p. 198; 'Journ. Inst. Electrical Engineers,' vol. 54, p. 419; 'Trans. Inst. Mining Engineers,' vol. 55, p. 245.

† "British Antarctic Expedition, 1910–1913"; 'Terrestrial Magnetism,' pp. 134, *et seq.*

Five days a month have been selected at De Bilt since 1906 as representative quiet days, and of late years five other days have been selected as representative disturbed days. For the earlier years I made the choice of disturbed days myself, selecting in each month the five of largest international "character." In quiet times the international quiet days have mostly characters 0·0, 0·1, and 0·2, but 0·4 or even 0·5 is met with occasionally in disturbed years. The "character" figures 1·9 and 2·0 do occur, but they are very rare. The "characters" of the great majority of the selected disturbed days exceed 1·0, but 0·9 and 0·8, or even 0·7, are occasionally encountered.

The primary object of the international scheme is to discriminate between the days of a single month. If the scale at a particular station were absolutely invariable, the result would be that in very quiet months nearly every day would get a 0, while in very disturbed months 0's would hardly exist. The objections to this lead the observer, consciously or unconsciously, to vary his standard, and whether a particular day is assigned a 1 or a 0 partly depends on whether it occurs in a quiet or a disturbed month. The same cause is operative everywhere, with the result that the mean "character" figure for a month or a year has no exact quantitative significance. The period 1906–20 has included some very quiet and some very disturbed years, yet the mean annual "character" figure has varied only from 0·455 in 1912 to 0·751 in 1918; and three years, 1909, 1915, and 1920, which were certainly not equally disturbed, had the identical figure, 0·620.

The size of the absolute daily range of declination (*i.e.*, westerly extreme—easterly extreme, irrespective of times of occurrence) is not determined solely by the amount of disturbance. Even the range of the diurnal inequality derived from the five quietest days of the month varies much with the season of the year and with sunspot frequency. The maximum generally occurs during the hours when declination is normally above its mean, and the minimum similarly in hours when declination is normally below its mean. Thus the size of the absolute range is partly determined—on quiet days mainly determined—by the amplitude of the regular diurnal variation. Consequently a considerably different degree of disturbance may be associated with the same absolute D range in different months, precisely as happens with the "character" figure.

Consideration of the above phenomena led to the use of the difference from the mean monthly value as the disturbance criterion both for "characters" and ranges.

§ 2. Taking n to denote a representative day—whether quiet or disturbed—in the month, the method adopted for exploring the 27-day period consists in entering in columns headed $n-2$, $n-1$, n, $n+1$, and $n+2$ the values of

the "character" or range for the representative day and the two days immediately preceding and following it. Taking the representative disturbed days, and supposing N of them, we sum the N entries in each of the five columns and take their means. The excesses of these means over the mean from all days represent the "primary pulse" of disturbance. In another series of columns headed $n+25$ to $n+30$ are entered the "characters" or ranges for days from 25 to 30 days later than the representative days. The excesses of the means from the N entries in each of these six columns over the corresponding all-day mean constitute the "secondary pulse."

The representative quiet days (or days of least range) are dealt with exactly in the same way. In their case the primary and secondary pulses show deficiencies below the all-day means.

The pulses associated with the disturbed days (or days of largest range) are described as "positive," those associated with the quiet days (or days of least range) are described as "negative."

For the primary pulse, whether positive or negative, the accepted all-day mean is that for the month or year to which the days in column n belong. For the secondary pulse in the yearly results a mean has been derived from the 12 months commencing with February of the current year. For the secondary pulse in the monthly tables the mean for the following month has been used. For instance, the data for 1906 in Table I represent in columns $n-2$ to $n+2$ the excess over 0·647, the mean for 1906, but in columns $n+25$ to $n+30$ the excess over 0·667, the mean from the 12 months February, 1906, to January, 1907. Similarly, the data for June in Table XII represent in columns $n-2$ to $n+2$ the deficiency from 14·68′, the mean range from all days of the 42 Junes, but in columns $n+25$ to $n+30$ the deficiency from 14·85′, the mean range from all days of the 42 Julys.

The average month contains 30 days, so there is not a full month between, for example, day n and day $n+27$. It did not, however, seem worth while attempting to allow for this. Another objection is that in the case of some months, notably January, there is a rather rapid rise (or fall) of range during the month and the following month. We may expect the selected days of small range to tend to come early, and those of large range to tend to come late in January, with a corresponding difference in the times of occurrence in February of the secondary pulse days. The all-day mean values employed would thus tend to be somewhat too large for the primary and secondary negative pulses, and too small for the primary and secondary positive pulses. The selected January days did, as a matter of fact, show the phenomenon, but not to the extent feared, the mean dates of the selected days of small and large range being respectively 13·1 and 16·5.

Some stations participating in the international scheme have dropped out and new ones have come in, and there have been many changes in personnel. Some stations again have intentionally changed their standard. Thus variations must have occurred in the international standard, quite apart from the psychological cause mentioned above, but the exact nature of these changes would be very difficult to ascertain.

Even the D ranges have experienced a small progressive change of standard. The disturbing force required to produce a given change of D varies directly as H (horizontal force component), and H at Kew increased from 0·175 in 1858 to 0·184 in 1900. Thus a change of 10·0′ in D in 1900 represented fully more disturbance than a change of 10·5′ in 1858.

§ 3. Tables I, II and III give the mean annual results from 1906–20, derived from the international "character" figures. Table I deals with the primary and secondary positive pulses derived from the selected disturbed days (five a month) and associated days. The figures represent excesses over the corresponding all day mean, except in the case of a minus sign, when there was a deficiency. The column headed S/P gives the ratio of the largest excess in the secondary pulse to the amplitude of the primary pulse in column n; the figure for 1908 for instance is derived from 0·210/0·664. The column headed S′/P′ gives the ratio of the largest sum from three adjacent columns in the secondary pulse to the sum of the entries in columns $n-1$, n, and $n+1$; in 1908, for instance, the figure is derived from $(0{\cdot}210 + 0{\cdot}207 + 0{\cdot}162) \div (0{\cdot}330 + 0{\cdot}664 + 0{\cdot}399)$.

Table II deals in a parallel fashion with the negative pulses, derived from the international quiet days and associated days. When, as usual, no sign is attached, the quiet or associated day's "character" was less than the all day mean value to the amount stated, but when a plus sign is attached it was in excess. The significance of S/P and S′/P′ is the same as in Table I.

Table III gives the difference pulses, primary and secondary, obtained by subtracting the sum of the "characters" for the quiet and associated days from the corresponding sum for the disturbed and associated days, and taking the mean of the differences. A minus sign means that the "character" figure from the representative disturbed or associated day was less than that from the representative quiet or associated day.

The figures in the columns $n-2$ to $n+30$ in Table III might have been derived by adding corresponding figures in Tables I and II, but they were derived independently as a check. A difference of one in the last decimal place arises occasionally from purely arithmetical causes. The entries under S/P and S′/P′ in Table III are derived from the pulses in that Table itself.

Table I.—Positive Pulses. International "Character" Figures.

Year.	Sunspot frequency.	Primary pulse.					Secondary pulse.						S/P.	S′/P′.
		$n-2$.	$n-1$.	n.	$n+1$.	$n+2$.	$n+25$.	$n+26$.	$n+27$.	$n+28$.	$n+29$.	$n+30$.		
1906	53·8	0·011	0·278	0·658	0·348	−0·015	−0·045	0·040	0·068	0·026	0·008	−0·040	0·10	0·10
1907	62·0	−0·020	0·297	0·665	0·304	0·067	−0·009	0·061	0·119	0·061	0·051	0·099	0·18	0·19
1908	48·5	−0·001	0·330	0·664	0·399	0·134	0·089	0·210	0·207	0·162	0·015	−0·023	0·32	0·42
1909	43·9	0·037	0·285	0·697	0·365	0·115	−0·095	−0·053	0·127	0·142	0·118	0·082	0·20	0·29
1910	18·6	0·045	0·252	0·584	0·317	0·172	−0·017	0·093	0·183	0·123	0·112	0·055	0·31	0·36
1911	5·7	−0·042	0·269	0·683	0·396	0·146	0·028	0·158	0·346	0·326	0·176	0·063	0·51	0·63
1912	3·6	−0·022	0·257	0·645	0·352	0·050	−0·012	0·166	0·271	0·116	0·045	−0·047	0·42	0·44
1913	1·4	0·132	0·348	0·662	0·368	0·147	0·094	0·234	0·317	0·231	0·146	0·111	0·48	0·57
1914	9·6	−0·005	0·200	0·650	0·318	0·133	0·031	0·016	−0·018	0·032	0·111	0·134	0·21	0·24
1915	47·4	−0·055	0·340	0·742	0·380	0·073	0·161	0·151	0·230	0·183	0·101	0·065	0·31	0·39
1916	55·4	−0·003	0·305	0·707	0·419	0·127	−0·076	−0·017	0·061	0·103	0·076	0·056	0·15	0·17
1917	103·9	−0·021	0·266	0·749	0·351	0·102	0·024	0·054	0·064	0·077	0·042	0·001	0·10	0·14
1918	80·6	0·069	0·396	0·732	0·372	0·137	0·100	0·167	0·125	0·109	0·079	0·037	0·23	0·27
1919	63·6	−0·091	0·272	0·742	0·441	0·107	−0·030	0·100	0·197	0·212	0·132	0·032	0·29	0·37
1920	38·7	−0·012	0·263	0·712	0·308	0·087	−0·031	0·137	0·264	0·180	−0·008	−0·048	0·37	0·45
Means, all years		0·001	0·291	0·686	0·363	0·106	0·015	0·102	0·171	0·139	0·081	0·039	0·25	0·31
A		−0·011	0·301	0·709	0·363	0·079	0·010	0·086	0·116	0·099	0·064	0·027	0·16	0·22
B		0·016	0·269	0·660	0·359	0·119	0·035	0·143	0·229	0·176	0·119	0·065	0·35	0·43
C		0·024	0·296	0·684	0·355	0·117	0·095	0·133	0·176	0·148	0·119	0·103	0·26	0·34
D		0·003	0·279	0·654	0·366	0·123	−0·002	0·115	0·227	0·174	0·093	0·026	0·35	0·40

Table II.—Negative Pulses. International "Character" Figures.

Year.	Primary pulse.					Secondary pulse.						S/P.	S′/P′.
	$n-2$.	$n-1$.	n.	$n+1$.	$n+2$.	$n+25$.	$n+26$.	$n+27$.	$n+28$.	$n+29$.	$n+30$.		
1906	0·132	0·317	0·502	0·275	0·115	0·087	0·197	0·234	0·130	0·037	+0·061	0·47	0·51
1907	0·131	0·333	0·515	0·240	+0·057	0·059	0·141	0·082	0·051	0·064	0·089	0·27	0·26
1908	0·096	0·305	0·523	0·268	+0·019	0·093	0·198	0·181	0·136	0·086	0·013	0·38	0·47
1909	0·143	0·295	0·513	0·275	0·038	0·005	0·052	0·100	0·112	0·098	0·023	0·22	0·29
1910	0·103	0·351	0·581	0·258	+0·039	0·050	0·177	0·218	0·215	0·045	+0·010	0·38	0·51
1911	0·104	0·277	0·516	0·194	+0·043	0·139	0·256	0·221	0·111	+0·043	+0·051	0·50	0·62
1912	0·022	0·190	0·413	0·143	+0·130	0·090	0·052	0·044	+0·033	+0·108	+0·025	0·22	0·25
1913	0·123	0·258	0·433	0·190	0·030	0·126	0·143	0·123	0·051	0·053	0·004	0·33	0·44
1914	0·073	0·295	0·468	0·160	0·018	0·018	0·058	0·084	0·114	0·079	0·076	0·24	0·30
1915	0·048	0·323	0·550	0·228	+0·020	0·102	0·164	0·225	0·194	0·114	0·102	0·41	0·53
1916	0·100	0·348	0·600	0·216	0·001	+0·049	+0·036	0·139	0·084	+0·018	+0·058	0·23	0·18
1917	0·083	0·303	0·573	0·246	0·046	0·066	0·164	0·103	0·048	0·068	0·046	0·29	0·30
1918	0·158	0·423	0·650	0·334	0·068	0·080	0·085	0·130	0·098	0·005	+0·020	0·20	0·22
1919	0·041	0·299	0·633	0·208	+0·097	0·120	0·038	0·061	+0·022	+0·022	+0·017	0·19	0·19
1920	0·093	0·318	0·537	0·160	+0·133	0·018	0·086	0·198	0·041	0·095	0·015	0·37	0·33
Means, all years	0·097	0·309	0·534	0·226	+0·015	0·066	0·118	0·142	0·088	0·036	0·008	0·27	0·33
A	0·109	0·335	0·575	0·261	0·015	0·081	0·123	0·120	0·059	0·029	0·006	0·21	0·28
B	0·080	0·255	0·457	0·172	+0·031	0·093	0·127	0·118	0·061	+0·005	0·001	0·28	0·38
C	0·082	0·293	0·484	0·193	0·010	0·082	0·122	0·144	0·120	0·082	0·061	0·30	0·40
D	0·094	0·284	0·509	0·228	+0·038	0·076	0·147	0·153	0·108	0·016	+0·010	0·30	0·40

Table III.—Difference Pulses. International "Character" Figures.

Year.	Primary pulse.					Secondary pulse.						S/P.	S′/P′.
	$n-2$.	$n-1$.	n.	$n+1$.	$n+2$.	$n+25$.	$n+26$.	$n+27$.	$n+28$.	$n+29$.	$n+30$.		
1906	0·143	0·595	1·160	0·623	0·100	0·042	0·237	0·302	0·157	0·045	−0·102	0·26	0·29
1907	0·112	0·630	1·180	0·543	0·010	0·050	0·202	0·202	0·112	0·115	0·188	0·17	0·22
1908	0·095	0·635	1·187	0·667	0·115	0·182	0·408	0·388	0·298	0·102	−0·010	0·34	0·44
1909	0·180	0·580	1·210	0·640	0·153	−0·090	−0·002	0·227	0·253	0·217	0·105	0·21	0·29
1910	0·148	0·603	1·165	0·575	0·133	0·033	0·270	0·402	0·338	0·157	0·045	0·35	0·43
1911	0·062	0·547	1·198	0·590	0·103	0·167	0·413	0·567	0·437	0·133	0·012	0·47	0·61
1912	0·000	0·447	1·058	0·495	−0·080	0·078	0·218	0·315	0·083	−0·063	−0·072	0·30	0·31
1913	0·255	0·607	1·095	0·558	0·177	0·220	0·377	0·440	0·282	0·198	0·115	0·40	0·49
1914	0·068	0·495	1·118	0·478	0·152	0·048	0·073	0·067	0·147	0·190	0·210	0·19	0·26
1915	−0·007	0·663	1·292	0·608	0·053	0·263	0·315	0·455	0·377	0·215	0·167	0·35	0·45
1916	0·097	0·653	1·307	0·635	0·128	−0·125	−0·053	0·200	0·187	0·058	−0·002	0·15	0·17
1917	0·062	0·568	1·322	0·597	0·148	0·090	0·218	0·167	0·125	0·110	0·047	0·16	0·21
1918	0·227	0·818	1·382	0·707	0·205	0·180	0·252	0·255	0·207	0·083	0·017	0·18	0·25
1919	−0·050	0·572	1·375	0·648	0·010	0·090	0·138	0·258	0·190	0·110	0·015	0·19	0·23
1920	0·082	0·582	1·248	0·468	−0·047	−0·013	0·223	0·462	0·222	0·087	−0·033	0·37	0·39
Means, all years	0·098	0·600	1·220	0·589	0·091	0·081	0·219	0·314	0·228	0·117	0·047	0·26	0·32
A	0·099	0·637	1·284	0·624	0·095	0·090	0·209	0·237	0·158	0·093	0·033	0·18	0·24
B	0·096	0·524	1·118	0·530	0·088	0·128	0·270	0·347	0·237	0·115	0·066	0·31	0·39
C	0·106	0·588	1·168	0·548	0·127	0·177	0·255	0·321	0·268	0·201	0·164	0·27	0·37
D	0·097	0·562	1·164	0·593	0·085	0·074	0·262	0·380	0·282	0·109	0·016	0·33	0·40

The last five lines in Tables I, II and III represent mean values from the whole 15 years, and four groups of years A, B, C, D, representing respectively large area of sunspots, small area of sunspots, high spot latitude and low spot latitude. Particulars are given presently.

A feature in the primary pulses calls first for remark. In Table I a minus sign occurs in 10 years in column $n-2$ and only once in column $n+2$, and the entry in column $n+1$ exceeds that in column $n-1$ in all but one year. In Table II, on the other hand, the plus sign occurs in column $n+2$ in 8 years, without occurring once in column $n-2$, and the entry in column $n-1$ is always (numerically) greater than that in column $n+1$. The positive and negative primary pulses are thus both markedly unsymmetrical.

The C.G. of the primary positive pulse falls in the interval between columns n and $n+1$, and the C.G. of the primary negative pulse in the interval between columns n and $n-1$. The exact physical significance of the phenomenon could be arrived at only by dealing with periods shorter than 24 hours, but the general explanation is as follows:

The day immediately following a large disturbance is seldom quiet, while the day preceding it is not infrequently quiet. In fact, one is sometimes tempted to think that a special calm has preceded the storm. Again—in Europe at least—large disturbance is much more common in (Greenwich) night hours than in the day hours, and the most disturbed hours precede midnight. The forenoon hours of a highly disturbed day are often quiet, at least at Kew. For the study of disturbance much could be said in favour of a "day" starting at Greenwich noon. It is a natural if not a certain inference from the phenomena that we may regard the centre of disturbance in the positive pulse as later in time, and the centre of quiet conditions in the negative pulse as earlier in time than noon of the representative day. The difference primary pulse in Table III, on the other hand, is very nearly symmetrical with regard to column n.

We shall first consider only the results for all years combined in Tables I, II and III. Each Table shows a conspicuous secondary pulse, the entry in column $n+27$ being decidedly the largest. The C.G. of the secondary pulse in Table I comes very sensibly on the up side of $n+27$ (*i.e.*, between columns $n+27$ and $n+28$); while in Table II it comes on the down side. In Table III it is slightly on the up side. The interval between the C.G.s of the primary and secondary pulses seems the same or very nearly the same in the three cases, and seems to slightly exceed 27 days.

Absolutely considered, the amplitude of the secondary negative pulse is less than that of the secondary positive pulse, but relative to the amplitude

of the primary pulse it is at least as large. The similarity of the values of S/P and of S′/P′ in Tables I and II seems hardly compatible with the suggestion which has been made that the 27-day period apparent in the quiet and associated days merely represents the fact that since highly disturbed days tend to be 27-day followers of highly disturbed days, all days other than disturbed days must have less than their fair share of such followers. Further evidence of the inadequacy of this explanation has been obtained by examining into the actual sequence of *q* and *d* (quiet and disturbed) days from 1906 to 1920. Omitting January, 1906, as no data were available for the previous month, we have a total of 895 selected days of either type. The *q* and *d* days each number practically a sixth of the total number of days. Thus the 27-day precursor of 895 average days should be a *d* day in 149 cases, and a *q* day in 149 cases. The totals actually observed were: *d* preceding *d* 257 cases, *q* preceding *q* 234 cases, *d* preceding *q* 98 cases and *q* preceding *d* 85 cases. If it were a matter of pure chance, the four sequences just specified should each occur ten times in 12 months. The *d* after *d* and *q* after *q* sequences exceeded expectation, the former in 14 the latter in 12 years. Only 1 year in either case gave a frequency less than ten. The *d* after *q* and *q* after *d* sequences fell short of expectation, the former in 14 the latter in 13 years, only 1 year in either case giving a frequency greater than ten.

In a sense it may be true that the 27-day period in quiet conditions is partly due to the scarcity of disturbed days among the 27-day followers of quiet days; but in the same way, and to approximately the same extent, the 27-day period in disturbed conditions is due to the scarcity of quiet days amongst the 27-day followers of disturbed days.

§ 4. Before discussing Tables I, II and III further, it will economise space to consider the general results derivable from Tables IV to VII, which refer to the Kew D ranges.

Some defects in the material first call for mention. The limits of registration were exceeded in a few days during magnetic storms. In such cases the value answering to the edge of the sheet was accepted, in place of the missing maximum or minimum. This entailed of course an under-estimate of the range. In most cases the under-estimate was probably small, and any effect on the mean ranges on which the Tables depend must have been trifling. On some days of apparently ordinary character there was a serious loss of trace, and a few days' trace was totally lacking. Such days, of course, had to be omitted. In a few cases days that would naturally have been selected disturbed or quiet days were omitted from the selected days because of the loss of trace on days which were 27 or 28 days later. Even a comparatively

TABLE IV.—Positive Pulses. Kew Declination Ranges.

Year.	Sunspot frequency.	Primary pulse.					Secondary pulse.					
		$n-2$.	$n-1$.	n.	$n+1$.	$n+2$.	$n+25$.	$n+26$.	$n+27$.	$n+28$.	$n+29$.	$n+30$.
1858	54·8	−0′·10	4′·16	13′·75	4′·51	−0′·37	−0′·23	1′·45	2′·46	2′·02	0′·30	−0′·23
1859	93·8	2·50	6·43	16·68	7·73	2·26	−0·32	1·00	2·25	0·28	0·22	0·94
1860	95·7	1·47	6·53	14·68	3·87	0·37	0·72	0·82	0·67	−0·06	−0·72	−0·04
1861	77·2	−0·05	6·53	14·51	5·03	2·20	1·08	3·20	2·28	1·69	0·37	1·04
1862	59·1	−0·24	4·66	15·82	4·59	−0·80	2·39	1·27	1·08	−0·08	−1·11	1·17
1863	44·0	−0·72	2·63	12·58	5·11	1·37	−0·33	1·01	3·38	2·56	1·79	1·06
1864	47·0	1·07	5·78	14·14	5·84	2·04	1·43	3·59	3·85	3·55	3·74	1·75
1865	30·5	0·40	5·72	16·06	6·18	1·59	−0·50	3·16	5·00	6·07	1·63	0·10
1866	16·3	−1·13	3·84	12·78	4·56	0·39	−0·18	0·82	1·16	1·87	2·03	0·20
1867	7·3	1·47	3·27	11·38	5·20	1·73	2·18	3·36	3·82	3·24	3·00	1·75
1868	37·3	−0·02	3·85	12·79	3·30	0·43	0·51	2·12	3·18	2·18	0·16	1·57
1869	73·9	−0·70	5·92	15·63	5·23	0·07	0·26	−0·79	0·94	2·61	0·81	−0·16
1870	139·1	0·10	7·23	15·94	4·83	−0·23	0·95	0·92	0·01	1·89	3·77	2·54
1871	111·2	−0·79	2·77	13·56	3·42	−0·54	−0·36	2·09	−0·26	−0·08	−0·98	−0·10
1872	101·7	−0·26	7·46	16·35	5·69	1·62	−0·22	2·22	1·73	2·69	2·32	0·56
1873	66·3	−1·47	2·94	11·55	2·35	0·51	−0·38	−0·49	−0·12	1·52	1·09	−1·76
1875	17·1	−0·97	1·51	7·95	2·51	0·35	0·40	0·78	0·65	1·85	0·11	−0·76
1876	11·3	−0·85	2·62	8·21	2·41	−0·66	0·24	−0·62	0·81	0·94	0·72	−0·06
1877	12·3	−0·87	2·31	7·74	2·62	0·19	0·04	2·22	1·60	0·90	−0·32	−0·87
1878	3·4	−0·41	2·24	6·18	1·99	−0·20	−0·54	0·35	1·15	0·52	−0·57	−0·09
1879	6·0	0·37	1·35	5·09	1·37	0·44	0·25	0·85	1·43	1·29	0·79	−0·23
1880	32·3	0·71	2·27	8·25	2·57	0·09	0·47	0·90	1·20	1·24	0·16	−0·31
1881	54·3	−0·57	2·52	7·38	1·93	−0·06	0·67	0·40	1·29	0·60	0·70	1·06
1882	59·7	−0·95	5·29	16·55	2·70	−0·16	−1·71	−0·29	0·55	−0·58	−0·50	0·11
1883	63·7	−1·06	3·89	11·52	3·27	1·14	−0·14	−0·11	1·04	0·20	1·57	0·82
1884	63·5	−0·23	3·61	9·14	3·07	−0·90	−1·04	0·19	0·94	0·68	−0·30	0·41
1885	52·2	0·17	2·24	9·56	2·71	0·66	0·12	0·49	1·01	1·37	1·33	0·71
1886	25·4	1·01	4·25	12·12	3·87	1·07	0·08	2·37	4·27	5·00	2·17	1·35
1887	13·1	0·75	3·45	9·13	4·33	1·51	−0·63	1·46	2·38	3·73	2·34	0·95
1888	6·8	−0·02	3·55	9·61	2·70	−0·19	0·00	2·37	3·34	2·24	0·23	−0·85
1889	6·3	−1·03	1·31	7·88	1·91	0·81	−0·41	0·52	3·14	1·92	0·25	−0·70
1890	7·1	0·32	1·73	5·65	1·75	0·21	−0·09	0·69	0·62	0·46	0·76	1·15
1891	35·6	0·64	3·25	9·83	3·74	2·00	−0·10	1·60	1·49	2·70	1·71	0·47
1892	73·0	−1·54	6·30	17·04	5·20	0·60	−1·34	−1·32	1·41	1·29	0·53	−2·08
1893	84·9	−0·15	2·56	8·65	2·88	0·55	−0·12	0·29	0·80	1·61	0·79	0·50
1894	78·0	−0·91	3·74	15·29	5·31	0·91	−1·27	0·02	−0·05	0·60	1·21	2·70
1895	64·0	0·01	2·35	10·14	3·52	1·53	−0·79	0·53	3·11	2·31	2·79	1·70
1896	41·8	0·65	4·15	11·66	5·87	2·66	1·76	2·88	3·60	3·84	2·90	0·55
1897	26·2	−1·37	2·63	9·21	2·24	−0·62	−0·28	1·13	1·61	1·25	−0·32	0·93
1898	26·7	0·18	4·64	10·69	3·53	0·39	0·65	0·73	2·62	2·74	2·74	0·68
1899	12·1	−0·33	2·68	8·56	2·57	0·85	0·51	2·42	2·26	1·41	0·05	−0·15
1900	9·5	−0·22	1·44	5·22	0·66	−0·17	0·31	1·01	0·30	−0·02	−0·10	0·71
Mean		−0·13	3·75	11·34	3·68	0·61	0·10	1·13	1·76	1·72	0·96	0·45

small loss of trace near the normal time of maximum or minimum disqualified a day for being a selected quiet day. A gap in the secondary pulse columns other than $n+27$ and $n+28$ was filled by interpolation from the ranges of the adjacent days. While it is only proper to mention these facts, it should be added that the defective days were so few that the exact procedure adopted could hardly matter.

Table V.—Negative Pulses. Kew Declination Ranges.

Year.	Primary pulse.					Negative pulse.					
	$n-2$.	$n-1$.	n.	$n+1$.	$n+2$.	$n+25$.	$n+26$.	$n+27$.	$n+28$.	$n+29$.	$n+30$.
1858	1′·46	4′·08	7′·16	3′·73	+0′·64	1′·43	1′·80	2′·29	2′·83	2′·01	+0′·45
1859	2·83	4·44	7·88	3·48	1·93	1·23	+0·59	+0·06	0·38	1·92	1·51
1860	0·17	3·02	7·66	2·72	0·92	+0·99	+1·20	+0·71	+0·93	0·77	+0·17
1861	2·49	4·14	7·18	2·23	+0·35	0·96	+0·20	0·53	+0·45	+2·02	+0·74
1862	+0·08	3·50	8·40	1·87	+1·57	1·27	2·18	1·08	+3·26	+0·50	+0·90
1863	2·66	4·12	8·08	2·14	+0·73	1·08	1·43	1·35	1·98	1·40	+0·17
1864	2·55	4·26	8·53	4·05	1·13	0·43	2·60	3·00	1·18	0·26	+1·00
1865	3·60	5·75	9·28	1·47	+2·06	1·39	2·19	3·09	2·30	1·20	+0·89
1866	2·40	3·12	7·98	3·78	+0·73	2·21	2·00	2·46	0·97	1·29	1·10
1867	1·60	3·16	6·02	2·56	0·51	1·30	1·62	2·81	0·45	+0·48	+0·09
1868	1·35	2·75	7·06	3·12	0·53	0·82	3·39	2·39	2·88	2·46	0·74
1869	0·15	4·36	8·14	4·76	1·67	+1·84	1·13	4·28	3·70	2·37	1·74
1870	1·13	2·52	7·98	2·35	1·07	+0·42	0·06	0·57	0·85	1·10	1·02
1871	0·31	2·66	7·56	2·23	+0·92	1·85	2·54	+0·30	+0·42	+0·54	+0·20
1872	1·92	4·47	8·60	2·66	+1·23	+1·05	2·14	3·35	3·08	+0·42	+2·56
1873	+0·57	1·72	5·91	0·33	+3·52	0·03	0·18	1·97	1·47	0·78	+1·00
1875	0·92	2·25	4·56	1·60	+0·35	1·10	1·13	0·59	0·86	+0·34	+1·56
1876	0·60	1·93	4·16	1·35	0·36	0·76	0·04	+1·09	0·28	0·50	0·48
1877	0·71	1·89	3·97	0·95	+0·69	+0·21	0·60	0·48	+0·27	+0·25	+0·19
1878	1·14	1·73	3·53	1·50	0·24	0·04	0·31	1·07	0·48	0·29	+0·19
1879	0·99	1·25	3·13	1·13	0·80	0·51	0·74	1·16	0·87	0·11	0·57
1880	+0·06	1·06	4·33	1·56	1·14	1·19	1·52	0·46	0·32	0·31	0·12
1881	+1·17	1·71	4·77	2·12	0·30	0·12	0·15	1·29	+0·60	+1·84	+1·35
1882	+0·45	2·38	7·28	2·44	+1·75	1·29	0·15	+0·42	0·29	2·25	+1·53
1883	1·02	2·16	6·44	1·87	+0·03	+0·79	1·67	1·75	1·77	+0·87	+0·94
1884	0·62	1·87	5·00	1·80	0·49	0·22	1·12	1·58	0·79	1·14	0·32
1885	0·26	2·32	5·18	1·64	0·10	0·47	0·02	0·80	+0·72	+0·03	0·82
1886	0·62	2·77	6·48	1·66	0·11	+0·83	0·89	2·10	1·30	1·25	+0·50
1887	0·74	2·83	5·37	2·30	0·14	0·54	1·19	1·41	1·21	1·08	+0·08
1888	1·64	2·90	5·30	1·26	0·14	1·42	2·21	1·48	1·16	+0·26	+1·17
1889	0·74	2·05	4·62	1·15	+0·26	0·65	1·13	1·26	0·63	+0·32	+0·62
1890	0·43	1·40	3·78	0·79	+0·26	0·46	0·12	0·66	0·23	0·37	0·64
1891	1·44	2·26	5·49	1·88	+0·79	0·80	1·48	0·29	0·77	+0·27	+1·43
1892	+1·73	3·91	7·66	3·68	0·83	+0·42	+0·66	+0·39	+0·21	1·08	2·98
1893	0·52	2·19	5·33	2·01	+0·79	1·73	1·40	1·00	0·36	0·68	0·00
1894	1·31	3·23	6·66	2·33	0·26	+1·22	1·17	2·40	0·17	2·67	2·77
1895	0·46	2·31	6·29	1·80	+0·35	0·95	1·64	1·83	0·98	0·38	0·35
1896	1·80	3·18	6·11	1·50	0·43	1·04	2·25	2·91	2·05	1·44	0·61
1897	0·54	2·68	5·14	1·31	0·24	+0·04	1·43	0·34	0·36	+1·29	0·07
1898	1·96	2·53	5·28	2·60	1·60	2·00	1·36	2·59	0·93	0·59	0·44
1899	1·12	2·07	4·72	1·92	0·48	1·30	0·96	1·85	1·08	1·04	+0·44
1900	+0·05	1·17	3·37	1·22	0·34	+0·51	+0·50	+0·17	+0·54	0·32	0·23
Mean ...	0·95	2·76	6·13	2·12	+0·03	0·53	1·07	1·32	0·75	0·51	+0·04

Table IV gives the positive pulses derived from the 5 days of largest range in each month and associated days; a minus sign signifies that the mean range from the disturbed or associated days fell short of the mean range from all days. Table V gives the negative pulses derived from the 5 days of least range in each month and associated days; a plus sign signifies that the mean range from all days was exceeded. Table VI gives the difference pulses

Table VI.—Difference Pulses. Kew Declination Ranges.

Year.	Primary pulse.					Secondary pulse.					
	$n-2$.	$n-1$.	n.	$n+1$.	$n+2$.	$n+25$.	$n+26$.	$n+27$.	$n+28$.	$n+29$.	$n+30$.
1858	1′·36	8′·24	20′·92	8′·24	−1′·01	1′·20	3′·25	4′·75	4′·86	2′·31	−0′·68
1859	5·33	10·86	24·55	11·21	4·19	0·92	0·41	2·19	0·67	2·14	2·46
1860	1·64	9·55	22·35	6·59	1·29	−0·27	−0·38	−0·05	−0·99	0·05	−0·21
1861	2·44	10·67	21·69	7·26	1·84	2·04	3·00	2·81	1·24	−1·65	0·31
1862	−0·31	8·16	24·21	6·46	−2·37	3·66	3·45	2·16	−3·34	−1·61	0·26
1863	1·95	6·75	20·66	7·25	0·64	0·75	2·45	4·73	4·54	3·19	0·89
1864	3·61	10·05	22·67	9·88	3·18	1·86	6·20	6·85	4·73	4·00	0·76
1865	4·00	11·47	25·34	7·66	−0·47	0·89	5·36	8·10	8·36	2·83	−0·78
1866	1·27	6·96	20·76	8·34	−0·34	2·03	2·81	3·62	2·84	3·32	1·30
1867	3·07	6·43	17·40	7·76	2·24	3·48	4·98	6·63	3·69	2·52	1·66
1868	1·33	6·60	19·85	6·42	0·96	1·33	5·51	5·57	5·06	2·63	2·31
1869	−0·54	10·29	23·77	9·99	1·75	−1·57	0·33	5·22	6·31	3·18	1·58
1870	1·23	9·75	23·91	7·18	0·85	0·53	0·98	0·58	2·74	4·87	3·56
1871	−0·48	5·43	21·12	5·65	−1·46	1·49	4·64	−0·56	−0·50	−1·53	−0·29
1872	1·66	11·93	24·95	8·35	0·38	−1·27	4·36	5·08	5·78	1·90	−2·00
1873	−2·04	4·66	17·45	2·68	−3·01	−0·35	−0·30	1·83	2·99	1·87	−2·76
1875	−0·04	3·76	12·51	4·11	0·00	1·50	1·90	1·23	2·71	−0·23	−2·32
1876	−0·25	4·56	12·37	3·76	−0·30	1·00	−0·58	−0·28	1·22	1·22	0·42
1877	−0·17	4·20	11·71	3·57	−0·49	−0·16	2·82	2·09	0·62	−0·58	−1·06
1878	0·73	3·97	9·70	3·49	0·05	−0·51	0·66	2·22	1·01	−0·28	−0·28
1879	1·36	2·61	8·22	2·50	1·24	0·76	1·59	2·60	2·16	0·90	0·34
1880	0·66	3·33	12·59	4·13	1·23	1·66	2·42	1·66	1·55	0·47	−0·20
1881	−1·74	4·23	12·15	4·06	0·24	0·79	0·54	2·58	0·00	−1·13	−0·29
1882	−1·40	7·67	23·83	5·14	−1·91	−0·42	−0·14	0·12	−0·28	1·75	−1·43
1883	−0·04	6·05	17·97	5·13	1·11	−0·93	1·56	2·79	1·96	0·70	−0·11
1884	0·40	5·47	14·14	4·86	−0·41	−0·82	1·31	2·52	1·47	0·84	0·72
1885	0·44	4·56	14·74	4·35	0·76	0·59	0·51	1·81	0·65	1·30	1·52
1886	1·62	7·02	18·60	5·53	1·19	−0·76	3·26	6·37	6·29	3·42	0·85
1887	1·50	6·28	14·50	6·63	1·65	−0·09	2·65	3·79	4·94	3·42	0·87
1888	1·62	6·44	14·92	3·96	−0·05	1·42	4·58	4·83	3·40	−0·03	−2·02
1889	−0·29	3·36	12·50	3·06	0·55	0·24	1·65	4·40	2·55	−0·07	−1·32
1890	0·75	3·13	9·43	2·54	−0·05	0·37	0·81	1·29	0·69	1·14	1·79
1891	2·08	5·51	15·32	5·62	1·21	0·71	3·08	1·78	3·47	1·43	−0·96
1892	−3·27	10·21	24·70	8·88	1·43	−1·75	−1·98	1·02	1·08	1·61	0·90
1893	0·38	4·76	13·98	4·89	−0·23	1·60	1·69	1·80	1·97	1·46	0·50
1894	0·40	6·97	21·95	7·64	1·17	−2·49	1·19	2·35	0·76	3·88	5·45
1895	0·47	4·67	16·43	5·31	1·18	0·15	2·16	4·94	3·30	3·18	2·05
1896	2·45	7·32	17·77	7·38	3·09	2·81	5·12	6·51	5·89	4·34	1·16
1897	−0·83	5·30	14·35	3·55	−0·38	−0·32	2·56	1·95	1·61	−1·61	1·00
1898	2·14	7·17	15·97	6·13	1·99	2·66	2·09	5·22	3·67	3·33	1·12
1899	0·79	4·75	13·29	4·49	1·33	1·82	3·37	4·11	2·49	1·09	−0·59
1900	−0·27	2·61	8·60	1·88	0·17	−0·20	0·51	0·13	−0·56	0·22	0·94
Mean (42 yrs.)	0·83	6·52	17·47	5·80	0·58	0·63	2·20	3·08	2·47	1·47	0·41

representing the mean excess in range of the days of large range or associated days over the days of small range or associated days; a minus sign implies that the mean range from the days associated with the days of largest range was the smaller.

It will be noticed that the majority of the entries in column $n-2$ of Table IV have the minus sign, and that a plus sign occurs with nearly half

Table VII.—Kew Declination Ranges. Groups of Years.

	Years.	Primary pulse.					Secondary pulse.						S/P.	S′/P′.
		$n-2$.	$n-1$.	n.	$n+1$.	$n+2$.	$n+25$.	$n+26$.	$n+27$.	$n+28$.	$n+29$.	$n+30$.		
		′	′	′	′	′	′	′	′	′	′	′		
Large ranges	All	−0·13	3·75	11·34	3·68	0·61	0·10	1·13	1·76	1·72	0·96	0·45	0·16	0·25
	A	−0·18	5·04	13·98	4·41	0·67	−0·31	0·63	1·10	1·08	0·85	0·64	0·08	0·13
	B	−0·16	2·48	8·12	2·67	0·41	0·14	1·29	1·83	1·54	0·76	0·15	0·23	0·35
	C	0·17	4·37	12·25	3·75	0·43	0·00	0·64	1·35	1·22	0·67	0·37	0·11	0·16
	D	−0·30	3·25	9·52	3·14	0·37	−0·06	1·57	2·14	2·07	0·77	0·16	0·22	0·36
Small ranges	All	0·95	2·76	6·13	2·12	+0·03	0·53	1·07	1·32	0·75	0·51	+0·04	0·22	0·29
	A	0·77	3·12	7·12	2·60	0·13	0·11	0·74	1·10	0·74	0·75	0·32	0·15	0·20
	B	1·01	2·13	4·66	1·66	0·09	0·71	0·87	1·12	0·55	0·31	0·02	0·24	0·32
	C	0·50	2·70	6·33	2·60	0·44	0·32	0·62	0·91	0·88	0·97	0·34	0·15	0·24
	D	1·38	2·67	5·39	1·83	+0·03	0·81	1·17	1·46	0·77	0·40	+0·11	0·27	0·35
Difference pulses	All	0·83	6·52	17·47	5·80	0·58	0·63	2·20	3·08	2·47	1·47	0·41	0·18	0·26
	A	0·59	8·16	21·10	7·01	0·80	−0·20	1·37	2·20	1·82	1·60	0·96	0·10	0·15
	B	0·84	4·61	12·79	4·33	0·50	0·85	2·16	2·95	2·09	1·07	0·17	0·23	0·33
	C	0·68	7·08	18·58	6·35	0·88	0·33	1·26	2·25	2·10	1·64	0·71	0·12	0·19
	D	1·08	5·92	14·91	4·97	0·35	0·75	2·74	3·61	2·84	1·17	0·05	0·24	0·36

the entries in column $n + 2$ of Table V. There are, however, an appreciable number of minus signs in column $n + 2$ of Table IV, and of plus signs in column $n - 2$ of Table V. Thus, while there is asymmetry similar to that in Tables I and II, it is less marked.

Sometimes a range exceeding the mean for the month was observed in a decidedly quiet day, and in one or two exceptionally quiet months the selected days of largest range included a day of this character. But the very large majority of the selected days of largest range were amongst the most disturbed days of the month. A small range might mean that disturbing forces were present, but happened to oppose the ordinary diurnal variation. This may have occurred in a few cases, but the selected days of least range undoubtedly represented in all months a much quieter set of conditions than the average day.

The mean results from the whole 42 years are given in the last lines of Tables IV, V, and VI. All show a well developed secondary pulse, the entry in column $n + 27$ being the largest. In Table IV the excess of the entry in column $n + 27$ over that in column $n + 28$ is small. Also the primary pulse is nearly symmetrical about column n, much more nearly so than the primary pulse in Table I; thus the period suggested is very decidedly in excess of 27 days. The negative pulses in Table V show a close parallelism to those in Table II, and suggest a period of very nearly 27 days. In Table VI the crest of the primary difference pulse seems slightly in advance of column n, and the crest of the secondary difference pulse slightly later than column $n + 27$, so that a period slightly in excess of 27 days is indicated.

§ 5. Before considering individual years, it is desirable to consider the results for the four groups of years in Tables I, II, III, and VII. The groups of years A, B, C, D were made up as follows, the first set of data in each case referring to the earlier period 1858–1900, the second to the later period 1906–1920.

For the information in the last column I am indebted to the Astronomer Royal, and to a paper by Mr. E. W. Maunder.*

There is a close relationship, at least approximately linear, between the range of the regular diurnal inequality of D (or other magnetic element) and sunspot frequency, the range being much larger in years of many than in years of few sunspots. The relationship of disturbance to sunspot frequency is less definite. Sunspot minimum is usually a very quiet time. Some years of great sunspot development are not specially disturbed, but most years of large sunspot frequency are more disturbed than the average year. Thus we should expect the amplitudes of the primary pulses to be above the average in the groups A, and below the average in groups B, and this is what we

* 'R. A. S. Notices,' vol. 74, p. 112.

Group.	Number of years.	Individual years.	Sunspot data.	
			Wolfer's frequency.	Mean equatorial distance.
A	14	1859, '60, '61, '69, '70, '71, '72, '82, '83, '84, '92, '93, '94, '95	84·2	15°·9
	5	1906, '07, '17, '18, '19 ...	72·8	?
B	12	1866, '67, '76, '77, '78, '79, '87, '88, '89, '90, '99, 1900	9·3	11·5
	4	1911, '12, '13, '14...	5·1	14·9
C	13	1858, '59, '60, '68, '69, '70, '79, '80, '81, '82, '90, '91, '92	58·7	19·7
	3	1913, '14, '15...	19·5	21·3
D	10	1865, '66, '77, '78, '87, '88, '97, '98, '99, 1900 ...	15·7	8·8
	5	1908, '09, '10, '11, '12 ...	24·1	9·0

actually observe in Tables I, II, and III, and to a more marked extent in Table VII. But it is very different with the secondary pulses. In spite of the diminished amplitude of the primary positive pulse in sunspot minimum years, the amplitude of the secondary positive pulse in Tables I and VII is much larger for group B than for group A years. The same is true of the difference pulses in Tables III and VII. Absolutely considered, the amplitude of the secondary negative pulse is much the same for group A and group B years in Tables II and VII, but the values of S/P and S′/P′ are much larger for the sunspot minimum groups. The groups C and D of high and low spot latitude years employed in Tables I, II, and III differ little in mean sunspot frequency, and the primary pulses reflect this approach to equality. The amplitude of the secondary pulse is decidedly larger for the D group in all three Tables, and the values of S/P and S′/P′ for this group are also decidedly the larger in Tables I and III.

In Table VII the C group had a much higher mean sunspot frequency than the D group, and this is reflected in the higher amplitude of the primary pulses of the former group. But in spite of this the secondary pulses associated with the D group are all much the larger. The values of S/P, in fact, for both the positive and difference pulses, are twice as large for the D as for the C group.

In view of the much larger number of years it is based on, we should naturally assign more weight to Table VII than to Tables I, II, and III, and hence conclude that low sunspot frequency and a low latitude of spots both conduce to the development of the 27-day period.

§ 6. The primary object in forming groups C and D was to see whether the interval between the crests of the primary and secondary pulses differed sensibly in years of high and low sunspot latitude. Mr. and Mrs. Maunder* give two tables for the synodic periods of sunspots in zones of different latitudes. The second Table, confined to recurrent spots, gives values very sensibly greater, especially for low latitudes, than the first Table, which includes short-lived spots. The recurrent spot data seem clearly those appropriate in the present case. From these we should infer synodic periods of 26·9, 27·2, and 27·3 days respectively for solar latitudes of 9°, 20°, and 21°. Thus the synodic period should be from 0·3 to 0·4 days longer for the group C than the group D years. The question is whether any such difference occurs in the interval between the crests of the primary and secondary pulses of magnetic "character," or range, in groups C and D?

There is a slight suggestion of a difference in the direction indicated in the case of the negative pulses in Table II, but Table I points the other way, the excess in the entry in column $n + 28$ over that for column $n + 26$ being largest in the D group. In Table III, the C.G. of the secondary pulse seems a shade later in the D than in the C group, but the same is true of the primary pulse. There is no clear variation in the interval, and certainly no suggestion of a difference as large as 0·4 day.

In Table VII, the interval between the crests of the primary and secondary positive pulses seems as nearly as possible the same for groups C and D. The secondary negative pulse for group C has a nearly flat top. If there is a single maximum, it would seem to fall decidedly later than in the D group; but this is compensated to some extent by the earlier occurrence of the primary crest in the latter group. In the case of the difference pulses the interval between the crests does seem sensibly longer for the C group, and the difference in length might be as large as 0·3 day. But, however this may be, it seems clear that the interval for the D group is in excess of 27 days, and not less.

In considering this question importance attaches to a result emphasised by Mr. and Mrs. Maunder, viz., that whilst the synodic period increases steadily with the latitude, when we take mean figures from a large number of spots, a considerable range of period is observed in spots having the same latitude. If only a moderate percentage of all the spots were effective for disturbing the earth's magnetic field, it might happen, at least in an individual year, that the mean synodic period of those effective differed very sensibly from the period appropriate to the mean spot latitude of the year. This in fact would be more than a possibility if the percentage of spots that are effective

* 'R. A. S. Notices,' vol. 65, p. 813.

increased as the latitude diminished. In that event the synodic period of the average effective spot would naturally be shorter than the mean spot latitude of the year.

In view of the interest which this question possesses in connection with theories which suppose sunspots to be the actual sources of electrical discharges causing magnetic storms,* it seemed worth while to consider the apparent variations in the position of the maximum of the secondary pulse in individual years. We must expect a considerable accidental element, so that what we have to consider is whether the majority of the years in which the period is specially long or specially short have any common sunspot characteristic. As the primary difference pulse is the most symmetrical, and the secondary difference pulse is that least exposed to accidental features, attention is confined to it.

Considering Tables VI and III we find the interval to be 28 days or more in the years 1858, '65, '69, '70, '72, '73, '75, '76, '82, '87, '91, '92, '93, '94, 1909 and 1914, and 26 days or less in 1861, '62, '71, '77, '80, '97, 1908 and 1917.

There does not seem any approach to a common characteristic in either group. Both contain years of many and years of few spots, and also years of high and years of low latitude.

§ 7. The years in which the 27-day period is best displayed include 1858, '63, '64, '65, '67, '68, '69, '72, '86, '87, '88, '89, '95, '96, '98, '99, 1910, '11, '13, '15 and '20. These are mostly years when spot latitudes were low, but there are notable exceptions to this including 1858, 1868, 1869 and 1913. Amongst the earlier group of years 1865 is pre-eminent, and amongst the later years 1911.

The years in which the 27-day period is least apparent include 1860, '71, '76, '82, '85, '90, '92, 1900, '07, '09, '14 and '16.

The failure of the secondary negative pulse in 1860 was mainly due to the fact that the 27-day followers of three of the days of least range in July belonged to a series of seven consecutive days of large disturbance. In 1882 the largest range of the year (2° 18·0′) occurred on a day which was a 27-day follower of one of the selected days of least range, and the next highest range (2° 12·2′) occurred on a 28-day follower. These were amongst the largest ranges of the 42 years. But for their "chance" occurrence, the year 1882 would have exhibited a normal negative pulse. An "accident" of this kind

* Since the preparation of this paper was completed a paper has appeared in the 'R. A. S. Notices' (vol. 82, p. 170), by the Rev. A. L. Cortie, who claims to have found a close agreement between the synodic periods of sunspots in different latitudes and the "repetition" periods derived from certain magnetic storms which he associates with the sunspots. His synodic periods seem decidedly in excess of those given by Mr. and Mrs. Maunder for the same latitudes.

is much more fatal to the secondary pulse than is the corresponding "accident" of days of small range being followers of days of large range. These "accidents" may, however, be less fortuitous than we should naturally suppose. At all events, it will be seen that years in which the negative secondary pulse was badly developed showed also as a rule poorly developed positive secondary pulses.

§ 8. For the consideration of the annual variation in the 27-day period, a knowledge is desirable of the mean "character," figures, and mean ranges, for the 12 months, derived from all the years combined. These are as follows:—

	"Character." 1906–1920.	D. range. 1858–1900.
January	0·618	12′·07
February	0·679	14·53
March	0·709	16·40
April	0·623	16·87
May	0·632	14·93
June	0·553	14·68
July	0·561	14·85
August	0·659	16·12
September	0·698	16·28
October	0·695	15·92
November	0·602	13·41
December	0·590	10·93

In both cases there is a double oscillation, with maxima towards the equinoxes and minima near the solstices. The chief difference is that June shows the lowest "character," December the lowest range. But the absolute range, as stated above, is partly determined by the regular diurnal variation, and the amplitude of the diurnal inequality is much larger at Kew (a northern station) in June than in December. The character of an individual month, as regards disturbance, cannot, of course, be safely deduced from the five most disturbed days. Table VIII represents, however, mean results from the selected disturbed days of 15 years. Thus one would expect a fairly close parallelism between the annual variation in the amplitude of the primary pulse in Table VIII, and the variation shown above in the mean "character" figures for the 12 months. In both cases, when the months are arranged according to amplitude, the equinoctial months March, September, and October, come at the top, and June at the foot. The order of the intermediate months differs considerably in the two cases, but the differences between the figures for August, May, April, July, and January, in Table VIII, are so small that the precise order in which these months occur possesses little significance. The chief difference is as regards February, on the one hand, and November and December on the other. February would seem to be a month when

disturbances are numerous but few outstanding, while November and December are months in which the largest disturbances overshadow the others.

The amplitudes of the primary negative pulse in Table IX, and of the primary difference pulse in Table X, show at least as close a parallelism in their annual variation to the mean "character" figures as does the amplitude of the positive pulse, July falling to the second lowest place, and November and December coming nearer the foot.

If the months were arranged according to the amplitude of the primary D pulse, their order would be precisely the same in Tables XI and XIII. October, November, February, and March, coming at the top, in the order stated, and August, May, July, and June, coming at the bottom. The order in Table XII would be only slightly different.

The annual variation in the amplitude of the primary difference pulses in Tables X and XIII shows a very regular progression. In both cases, too, we have a minimum in June and a maximum in October. Table XIII differs from Table X chiefly in that November and February come more to the front, while September and March retire.

All the months in Tables VIII, IX, XI, and XII show distinct secondary pulses; the 27-day period is clearly existent in all months of the year. The incidence of the crest of the secondary pulse seems, however, rather irregular, especially that of the negative pulse. This phenomenon, especially in the case of the D range, is probably, in part, an indirect consequence of the considerable amplitude of the annual range. Take, for instance, the D range phenomena associated with the January primary pulses. The range is naturally rising during the occurrence of the secondary pulses. For absolute accuracy the normal range should rise gradually from column $n + 25$ to column $n + 30$, while the mean value for February has been used in all these columns. The natural consequence of this would be a gradual algebraical increase from column $n + 25$ to column $n + 30$ of the positive pulse, and a corresponding numerical fall in the negative pulse. This, it will be seen, is what the negative pulse actually shows, though this may not be the only cause of the phenomenon. The difference pulses should be free from this defect, and they are, in fact, much more regular. The maximum in the secondary pulse appears in column $n + 27$ in 9 months out of the 12 in both Tables X and XIII. In Table X the maximum is found twice in column $n + 26$, and once in column $n + 28$. In Table XIII it occurs thrice in column $n + 28$. The exceptions occur in only one case in the same month, January, and the excess of the entry in column $n + 28$, over that in column $n + 27$ in the January figures in Table X, is trifling. There is thus no real indication of a seasonal variation in the length of the period.

Table VIII.—Positive Pulses. International "Character" Figures. Annual Variation.

Month.	Primary pulse.					Secondary pulse.						S/P.	S′/P′.
	$n-2$.	$n-1$.	n.	$n+1$.	$n+2$.	$n+25$.	$n+26$.	$n+27$.	$n+28$.	$n+29$.	$n+30$.		
January	0 ·062	0 ·243	0 ·665	0 ·365	0 ·178	0 ·033	0 ·134	0 ·182	0 ·192	0 ·125	0 ·076	0 ·29	0 ·40
February	−0 ·004	0 ·237	0 ·634	0 ·348	0 ·138	0 ·015	0 ·064	0 ·163	0 ·122	0 ·094	0 ·062	0 ·26	0 ·31
March	0 ·063	0 ·402	0 ·734	0 ·427	0 ·166	0 ·064	0 ·176	0 ·206	0 ·140	0 ·128	0 ·134	0 ·28	0 ·33
April	−0 ·055	0 ·298	0 ·674	0 ·302	0 ·086	0 ·073	0 ·101	0 ·104	0 ·099	0 ·019	−0 ·037	0 ·15	0 ·24
May	0 ·011	0 ·312	0 ·676	0 ·380	0 ·093	0 ·072	0 ·159	0 ·211	0 ·175	0 ·043	−0 ·042	0 ·31	0 ·40
June	−0 ·010	0 ·351	0 ·626	0 ·364	0 ·148	−0 ·036	0 ·032	0 ·110	0 ·072	0 ·014	0 ·022	0 ·18	0 ·16
July	−0 ·037	0 ·234	0 ·672	0 ·332	0 ·076	0 ·014	0 ·069	0 ·185	0 ·170	0 ·110	0 ·028	0 ·28	0 ·38
August	−0 ·064	0 ·245	0 ·689	0 ·342	0 ·021	−0 ·011	0 ·147	0 ·209	0 ·113	0 ·054	0 ·014	0 ·30	0 ·37
September ...	−0 ·007	0 ·289	0 ·718	0 ·387	0 ·142	0 ·029	0 ·086	0 ·244	0 ·217	0 ·180	0 ·086	0 ·34	0 ·46
October	0 ·064	0 ·297	0 ·736	0 ·452	0 ·177	0 ·043	0 ·139	0 ·153	0 ·166	0 ·099	0 ·081	0 ·23	0 ·31
November ...	−0 ·019	0 ·267	0 ·706	0 ·330	0 ·066	−0 ·038	0 ·085	0 ·127	0 ·097	0 ·033	0 ·039	0 ·18	0 ·24
December......	0 ·018	0 ·314	0 ·705	0 ·322	−0 ·025	−0 ·076	0 ·033	0 ·169	0 ·119	0 ·079	−0 ·001	0 ·24	0 ·27
Mean ratios...												0 ·25	0 ·32

Table IX.—Negative Pulses. International "Character" Figures. Annual Variation.

Month.	Primary pulse.					Secondary pulse.						S/P.	S′/P′.
	$n-2$.	$n-1$.	n.	$n+1$.	$n+2$.	$n+25$.	$n+26$.	$n+27$.	$n+28$.	$n+29$.	$n+30$.		
January	0 ·018	0 ·287	0 ·523	0 ·139	+0 ·043	+0 ·017	0 ·039	0 ·038	0 ·038	0 ·066	0 ·106	0 ·20	0 ·22
February	0 ·064	0 ·258	0 ·538	0 ·184	+0 ·077	0 ·105	0 ·217	0 ·224	0 ·073	0 ·061	0 ·045	0 ·42	0 ·56
March	0 ·170	0 ·374	0 ·605	0 ·321	+0 ·008	0 ·063	0 ·199	0 ·196	0 ·108	+0 ·009	+0 ·057	0 ·33	0 ·39
April	0 ·107	0 ·294	0 ·539	0 ·231	0 ·020	0 ·105	0 ·092	0 ·068	0 ·055	+0 ·004	0 ·009	0 ·19	0 ·25
May	0 ·060	0 ·284	0 ·501	0 ·233	0 ·088	0 ·053	0 ·140	0 ·122	0 ·062	0 ·001	+0 ·046	0 ·28	0 ·32
June	0 ·102	0 ·289	0 ·469	0 ·218	+0 ·084	0 ·076	0 ·152	0 ·144	0 ·061	0 ·008	0 ·010	0 ·32	0 ·38
July	0 ·124	0 ·309	0 ·481	0 ·229	0 ·068	0 ·018	0 ·022	0 ·096	0 ·080	0 ·078	0 ·107	0 ·22	0 ·26
August.........	0 ·055	0 ·303	0 ·556	0 ·224	+0 ·042	0 ·134	0 ·166	0 ·174	0 ·137	0 ·095	0 ·050	0 ·31	0 ·44
September ...	0 ·113	0 ·341	0 ·589	0 ·207	+0 ·057	0 ·103	0 ·078	0 ·155	0 ·147	0 ·096	+0 ·013	0 ·26	0 ·35
October	0 ·191	0 ·388	0 ·603	0 ·279	0 ·070	0 ·195	0 ·185	0 ·142	0 ·025	+0 ·013	+0 ·030	0 ·32	0 ·41
November ...	0 ·051	0 ·277	0 ·497	0 ·257	+0 ·075	+0 ·073	+0 ·001	0 ·114	0 ·129	0 ·093	0 ·026	0 ·26	0 ·33
December ...	0 ·102	0 ·303	0 ·502	0 ·191	+0 ·037	0 ·027	0 ·117	0 ·231	0 ·136	+0 ·043	+0 ·120	0 ·46	0 ·49
Mean ratios...												0 ·30	0 ·37

Table X.—Difference Pulses. International "Character" Figures. Annua Variation.

Month.	Primary pulse.					Secondary pulse.						S/P.	S′/P′.
	$n-2$.	$n-1$.	n.	$n+1$.	$n+2$.	$n+25$.	$n+26$.	$n+27$.	$n+28$.	$n+29$.	$n+30$.		
January	0 ·080	0 ·530	1 ·188	0 ·504	0 ·135	0 ·016	0 ·173	0 ·220	0 ·230	0 ·191	0 ·182	0 ·19	0 ·29
February	0 ·060	0 ·495	1 ·172	0 ·532	0 ·061	0 ·120	0 ·281	0 ·387	0 ·195	0 ·155	0 ·107	0 ·33	0 ·39
March	0 ·233	0 ·776	1 ·339	0 ·748	0 ·158	0 ·127	0 ·375	0 ·402	0 ·248	0 ·119	0 ·077	0 ·30	0 ·36
April	0 ·052	0 ·592	1 ·213	0 ·533	0 ·106	0 ·178	0 ·193	0 ·172	0 ·154	0 ·015	−0 ·028	0 ·16	0 ·23
May	0 ·071	0 ·596	1 ·177	0 ·613	0 ·181	0 ·125	0 ·299	0 ·333	0 ·237	0 ·044	−0 ·088	0 ·28	0 ·37
June	0 ·092	0 ·640	1 ·095	0 ·582	0 ·064	0 ·040	0 ·184	0 ·254	0 ·133	0 ·022	0 ·032	0 ·23	0 ·25
July	0 ·087	0 ·543	1 ·153	0 ·561	0 ·144	0 ·032	0 ·091	0 ·281	0 ·250	0 ·188	0 ·135	0 ·24	0 ·32
August	−0 ·009	0 ·548	1 ·245	0 ·566	−0 ·021	0 ·123	0 ·313	0 ·383	0 ·250	0 ·149	0 ·064	0 ·31	0 ·40
September ...	0 ·106	0 ·630	1 ·307	0 ·594	0 ·085	0 ·132	0 ·164	0 ·399	0 ·364	0 ·276	0 ·073	0 ·31	0 ·41
October	0 ·255	0 ·685	1 ·339	0 ·731	0 ·247	0 ·238	0 ·324	0 ·295	0 ·191	0 ·086	0 ·051	0 ·24	0 ·31
November ...	0 ·032	0 ·544	1 ·203	0 ·587	−0 ·009	−0 ·111	0 ·084	0 ·241	0 ·226	0 ·126	0 ·065	0 ·20	0 ·25
December......	0 ·120	0 ·617	1 ·207	0 ·513	−0 ·062	−0 ·049	0 ·150	0 ·400	0 ·255	0 ·036	−0 ·121	0 ·33	0 ·34
Mean ratios ...												0 ·26	0 ·33

Table XI.—Positive Pulses. Kew D Ranges. Annual Variation.

Month.	Primary pulse.					Secondary pulse.						S/P.	S′/P′.
	$n-2$.	$n-1$.	n.	$n+1$.	$n+2$.	$n+25$.	$n+26$.	$n+27$.	$n+28$.	$n+29$.	$n+30$.		
January	−0′·65	3′·65	12′·21	4′·32	1′·64	−0′·73	−0′·41	0′·99	2′·50	1′·43	1′·31	0 ·20	0 ·26
February	0 ·11	5 ·35	13 ·54	5 ·32	1 ·10	0 ·20	1 ·42	1 ·62	1 ·25	0 ·92	0 ·67	0 ·12	0 ·18
March	−0 ·72	3 ·69	12 ·25	3 ·53	−0 ·60	0 ·20	1 ·53	2 ·68	2 ·36	0 ·77	−0 ·19	0 ·22	0 ·34
April	−0 ·41	4 ·06	11 ·25	2 ·99	−0 ·40	0 ·09	1 ·29	1 ·89	1 ·75	0 ·70	0 ·08	0 ·17	0 ·27
May	−0 ·22	2 ·91	9 ·21	2 ·95	0 ·55	−0 ·01	0 ·67	1 ·74	1 ·19	0 ·30	0 ·46	0 ·19	0 ·24
June	−0 ·55	2 ·25	7 ·42	2 ·17	0 ·02	−0 ·03	0 ·69	0 ·90	0 ·71	0 ·24	0 ·23	0 ·12	0 ·19
July	0 ·26	2 ·87	8 ·42	2 ·13	0 ·96	−0 ·70	0 ·58	1 ·03	0 ·67	0 ·76	0 ·00	0 ·12	0 ·18
August	0 ·06	2 ·47	10 ·27	2 ·96	0 ·67	0 ·33	0 ·94	1 ·12	1 ·32	0 ·66	0 ·72	0 ·13	0 ·22
September ...	−0 ·11	4 ·06	11 ·95	3 ·87	0 ·03	0 ·46	2 ·19	2 ·52	2 ·25	1 ·62	0 ·68	0 ·21	0 ·35
October	0 ·71	4 ·51	13 ·83	4 ·81	1 ·48	0 ·15	2 ·57	2 ·52	2 ·49	1 ·84	0 ·91	0 ·19	0 ·33
November ...	0 ·01	5 ·65	13 ·71	4 ·94	1 ·29	1 ·58	1 ·81	2 ·70	2 ·50	1 ·91	0 ·90	0 ·20	0 ·29
December......	−0 ·21	3 ·31	11 ·91	3 ·98	0 ·30	−0 ·61	−0 ·06	1 ·25	1 ·56	1 ·20	0 ·10	0 ·13	0 ·21
Mean ratios ...												0 ·17	0 ·25

Table XII.—Negative Pulses. Kew D Ranges. Annual Variation.

Month.	Primary pulse.					Secondary pulse.						S/P.	S′/P′.
	$n-2$.	$n-1$.	n.	$n+1$.	$n+2$.	$n+25$.	$n+26$.	$n+27$.	$n+28$.	$n+29$.	$n+30$.		
January	2′·11	3′·86	6′·76	1′·66	+0′·07	2′·18	1′·99	1′·97	1′·81	1′·17	+0′·26	0·32	0·48
February	1·76	3·99	7·53	3·66	0·77	1·99	2·51	2·51	2·19	0·58	0·65	0·33	0·47
March	1·45	3·25	6·93	2·26	1·31	+0·65	0·38	0·62	+0·14	0·04	0·13	0·09	0·07
April...........	0·06	2·05	5·66	2·49	0·06	0·25	0·55	0·73	0·46	0·48	0·12	0·13	0·17
May	0·36	1·91	5·07	2·01	0·77	0·28	0·78	0·83	0·48	1·05	0·43	0·21	0·26
June	0·36	1·19	4·33	1·48	0·04	0·21	0·37	0·98	0·87	0·51	0·24	0·23	0·34
July	+0·12	1·36	4·76	1·64	+0·03	+0·07	0·78	1·28	0·34	0·14	+0·20	0·27	0·31
August	1·03	2·41	5·70	1·57	+0·20	0·34	0·79	0·81	0·71	0·43	+0·42	0·14	0·24
September ...	1·03	3·25	6·47	2·69	+0·19	0·48	1·23	2·13	1·03	0·73	+0·11	0·33	0·35
October	2·17	3·85	7·41	2·53	+0·76	0·19	0·98	0·86	1·09	1·36	+0·74	0·18	0·24
November ...	1·44	4·02	7·49	2·63	+0·60	0·34	1·64	1·64	0·89	+0·13	+0·33	0·22	0·29
December......	0·51	2·83	6·29	1·62	+0·38	1·19	1·35	1·87	+0·56	0·13	0·43	0·30	0·41
Mean ratios ...												0·23	0·30

Table XIII.—Difference Pulses. Kew D Ranges. Annual Variation.

Month.	Primary pulse.					Secondary pulse.						S/P.	S′/P′.
	$n-2$.	$n-1$.	n.	$n+1$.	$n+2$.	$n+25$.	$n+26$.	$n+27$.	$n+28$.	$n+29$.	$n+30$.		
January	1′·45	7′·51	18′·97	5′·98	1′·57	1′·45	1′·57	2′·95	4′·30	2′·59	1′·05	0·23	0·30
February	1·88	9·34	21·08	8·98	1·88	2·19	3·93	4·12	3·43	1·51	1·32	0·20	0·29
March	0·73	6·94	19·18	5·79	0·71	−0·44	1·90	3·31	2·22	0·81	−0·06	0·17	0·23
April	−0·35	6·12	16·91	5·48	−0·34	0·35	1·84	2·62	2·21	1·18	0·20	0·15	0·23
May	0·14	4·82	14·28	4·96	1·32	0·26	1·44	2·58	1·67	1·35	0·89	0·18	0·24
June	−0·19	3·44	11·75	3·65	0·06	0·18	1·06	1·87	1·58	0·75	0·47	0·16	0·24
July	0·14	4·24	13·18	3·78	0·93	−0·77	1·36	2·31	1·01	0·90	−0·19	0·18	0·22
August	1·08	4·88	15·96	4·53	0·47	0·67	1·72	1·93	2·04	1·08	0·30	0·13	0·22
September ...	0·92	7·30	18·42	6·55	−0·17	0·94	3·42	4·65	3·28	2·35	0·58	0·25	0·35
October	2·88	8·36	21·24	7·33	0·72	0·34	3·55	3·38	3·57	3·20	0·18	0·17	0·28
November ...	1·44	9·67	21·20	7·57	0·68	1·93	3·45	4·34	3·39	1·78	0·57	0·20	0·29
December ...	0·30	6·14	18·20	5·60	−0·08	0·58	1·29	3·12	1·00	1·33	0·53	0·17	0·18
Mean ratios ...												0·18	0·26

In both Tables X and XIII the amplitude is large in the secondary pulses associated with February, March, and September, and low in those associated with June and July. The secondary pulse, of course, occurs nearly a month later than the primary pulse with which it is associated. The annual variation in the amplitude of the secondary pulse is most regular in Table XIII, where it follows, on the whole, the variation in the primary pulse.

The values of S/P and S′/P′—quantities having the same significance as in the earlier Tables—are slightly less for summer than the other seasons in Table XIII. If the southern hemisphere were as strongly represented as the northern in the international lists, there should be no sensible difference between summer and winter in Table X, and as a matter of fact high and low values of S/P and S′/P′ occur rather promiscuously in that Table.

The variation in the position of the earth relative to the sun during its annual path has a marked effect on the amount of magnetic disturbance existing on the earth, but it seems to have little if any effect on the development of the 27-day period.

§ 9. In all terrestrial latitudes, so far as is known, the amplitude of the regular diurnal magnetic variation rises and falls with sunspot frequency. Again, it has been found that at least in high terrestrial latitudes the amplitude of the regular diurnal variation and the intensity of disturbance rise and fall together. It is thus natural to suppose that the increased amplitude of the regular diurnal variation in years of many sunspots is due to a solar radiation of the same type as the solar radiation causing magnetic disturbance or a very similar type. The difference very likely is merely in the regularity of the solar discharge. In years of many sunspots the large daily magnetic range is not a spasmodic feature. Small ranges, such as we meet with near sunspot minimum, simply do not exist. Consequently the solar discharge which influences the regular diurnal variation must be constantly operative. There is thus really nothing remarkable in the conclusion to which the present investigation points, viz., that it is not a question between magnetic storms and magnetic calms, but simply of disturbance above and below the average (*i.e.*, irregularity of solar discharge).

On the restricted view that magnetic storms are unique events, due to electrical discharges confined to sunspot areas, the existence of a 27-day period is an obvious corollary. But the existence of such a period does not by itself justify the conclusion that sunspots are the only sources, or even the principal sources, of the solar discharge. We should clearly still get a 27-day period if the whole solar surface were discharging, provided the discharge reaching the earth at any given instant came from a comparatively narrow zone, and the intensity were a function of the solar longitude which did not

vary two rapidly with the time. The period would naturally be less variable than if the radiation emanated only from isolated sunspots, but it might vary considerably if the latitude of most intense radiation varied.

Sunspots may be sources of specially vigorous solar discharges, or they may simply be symptoms that the sun is at the moment or recently has been specially active. Even in the quietest of years, and in the absence of visible sunspots, we have variations in the daily D range, and also at least minor disturbances; and, as the present investigation has conclusively shown, the 27-day period may be not merely recognisable but actually prominent in such a year. In fact 1913, with the lowest sunspot frequency since 1858, had the 27-day period particularly well developed.

It remains to express my indebtedness to the Government Grant Committee for the funds which rendered possible the measurement of the Kew declination ranges from 1858 to 1889. I have also to thank the Astronomer Royal for valuable information about sunspots and for useful references.

On Doubly-Resonated Hot-Wire Microphones.

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(Communicated by Prof. H. L. Callendar, F.R.S. Received March 30, 1922.)

§ 1. *Introduction.*—In the selective hot-wire microphone* a Helmholtz resonator is used for the detection of sound-waves of definite pitch. The resonator responds to the particular note to which it is tuned, and its response is measured by the change in resistance of an electrically heated platinum-wire grid mounted in the "neck" of the resonator.

The magnitude of the response depends in the usual manner on the tuning and damping of the receiving system, and therefore in order to obtain great sensitivity the damping must be small and consequently the resonance must be sharp. For some purposes, however, sharp resonance may be a disadvantage—as, for example, when the source of sound is liable to small variations in pitch, or when allowance must be made for the Doppler effect—while at the same time it may be desired to retain a high degree of sensitivity. Even in cases where very sharp tuning is permissible, the only effective means of increasing the acoustical sensitivity is by reducing the neck of the resonator, and since

* W. S. Tucker and E. T. Paris, 'Phil. Trans.,' A, vol. 221, pp. 389–430 (1921).